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(54) Title: A METHOD OF CONTROLLING THE MELT TEMPERATURE OF A PLASTIC MASS DURING MANUFACTURE OF PLASTIC ARTICLES

(57) Abstract

The present invention briefly refers to a method for controlling the melt temperature of plastic raw material during the manufacture of plastic articles. The desired melt temperature is obtained and/or maintained by changing the amount of mechanical energy supplied to the raw material in the plasticizing section.

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A METHOD OF CONTROLLING THE MELT TEMPERATURE OF A PLASTIC MASS DURING MANUFACTURE OF PLASTIC ARTICLES

The present invention relates to temperature control of machines intended to be used in the manufacture of plastic articles, in particular to a control rendering a desired melt temperature throughout the entire melt. The control in question is a control during production and not specifically the control only directed to heating and melting a raw material prior to starting the production.

The raw material used for the manufacture of plastic articles is supplied to the machine in granular, pulverized or otherwise disintegrated form, possibly together with additives such as dies, antioxidants, UV-stabilisators or the like. In the machine the raw material is mechanically kneaded, normally by means of a screw or the like rotating within a cylinder, said screw also providing the molten raw material to be homogenized, pressurized and discharged into a nozzle, casting machine, mould or similar tool endowing to the product its final shape prior to any additional working such as longitudinal and transverse stretching.

Normally working is performed with the aid of a screw rotating within a cylinder. The working is performed in a so-called working section from which the viscous plastic mass is fed through a screen pack assembly and an intermediate tube, so-called adapter, to the tool and wire via ducts or grooves therein out through the casting machine or out into the mould.

In addition to means for supplying mechanical energy by means the screw and cylinder the machine is provided with devices for heating and cooling. The heating device is so designed that parts or zones of the machine may be individually heated and controlled to the desired temperature independently of each other. The cooling is normally performed with the aid of

fans each performing the cooling of a section or zone of the machine. The various zones are provided with heat detectors, detection or measuring being performed within the metal mantle of the cylinder. Thus, the control of the temperature in the various zones of the cylinder will basically be a control of the temperature in the cylinder itself, i.e. a control of the metal temperature. In addition to the cylinder also the screw within the cylinder of the working section may be provided with devices for changing the temperature, e.g. in the form of cooling ducts and/or immersion heaters.

The primary reason for the temperatuare control of the working section is to arrive at a desired melt temperature. On the other hand, the reason for the heat control of the screen, adapter and tool and any additional equipment is to prevent the temperature of the molten plastic to change during the transfer to the die or corresponding section of the machine. In some of the processes a control of the nozzle temperature is performed for the purpose of giving the product produced a desired surface structure and desirable optical properties. The invention refers to all these different purposes and is intended to solve the various partial problems in the simpliest and most rational way.

The working section comprises a hopper for supplying the raw material, a screw rotating within a cylinder and a screen pack assembly containing a filter screen for filtering out contaminants from the melt. As mentioned above, there are a number of temperature-control zones where the metal temperature is adjusted to a desired value by applying both heating and cooling.

It is tempting to believe that an addition of the heat supplied by the heating elements and an increased metal temperature caused thereby would result in a higher melt temperature, but this is definitely not the case. Actually, an

increased supply of heating energy from the heating element may result in a decreased temperature of the melt and a reduced production capacity under otherwise constant production conditions.

It will be appreciated that the main portion of all the added energy is in the form of mechanical energy. The short dwell time, normally some minutes, in the working section in relation to the production capacity would require very high capacity of the heating elements to perform the task of melting the raw material alltogether, a capacity which certainly would burn the raw material adjacent to the heating element and thereby destroy it.

Friction and thereby frictional heat will be produced during the rotation of the screw between the granulate and the screw, between the granulate and the cylinder, between the various granules of the raw material and within the melt. A change of the coefficient of friction and the viscosity thus results in a change of the friction of heat supplied and thereby the melt temperature. Another influencing factor is the return flow around the screw. The reason therefore is that the screw does not operate with an absolute seal against the cylinder wall, a portion of the mass flowing back in the gap between the flights of the screw and the cylinder wall. The pressure ahead of the screen pack assembly and the viscosity of the mass are factors directly influencing the return flow. If an increase of the production is desired, the pressure must be increased, such increase directly changing the temperature of the melt and thereby the viscosity. Various raw materials have various coefficient of friction and in addition different viscosities at the same temperature. A higher viscosity requires an increased pressure in order to obtain constant production capacity. As defined, it contributes in addition to an increased frictional heat due to increased internal friction. A higher coefficient of friction melt/metal, granulate/metal

and/or granulate/granulate also contributes towards increased frictional heat.

A high surface temperature of the screw and/or cylinder melts the material which is in contact with the metal. This molten material acts as a lubricant and thus reduces the friction against the cylinder wall and/or the screw and thereby the frictional heat. The raw material normally is a polymer and has a varying molecular weight distribution between various qualities and also between various supplies of raw materials of the same specifications. The low molecular weights are melting at lower temperatures than the high molecular weights and in this case also act as a lubricant reducing the coefficient of friction.

From the above it will appear that the heat contribution from heating elements in a high degree may change the conditions of friction and thereby the supply of frictional heat. Accordingly, in order to be maintained at a constant value, this contribution should be adapted to the temperature of the melt or raw material in every zone with a constant temperature deviation in relation to said temperature. In order to obtain this result in practice, a temperature detector is positioned as close as possible to the inside surface of the cylinder or alternatively as a part thereof in order to obtain an optimum temperature measuring of the melt or raw material. A second temperature detector is positioned close to the outside surface of the cylinder and this temperature is controlled to follow the melt or raw material temperature with a desired temperature deviation in order to supply desired frictional heat to the zone in question. In those cases where also the screw is temperature-controlled the same principle may be applied for this control. Certain geometrical shapes of the screw may supply too much or too little frictional heat and this may be compensated according to the above-explained principle.

It is obvious that the frictional heat provides practically all the energy supplied to the melt and thereby determines the melt temperature obtained. The supply of energy from heating elements only complicates the problem to obtain the desired melt temperature. If instead the process is controlled exclusively by controlling the mechanically supplied energy for a given production, it will be possible to arrive at a desired melt temperature independent of variations of the raw material and the capacity in a simplier and quicker way.

From the above explanation it will also appear that a change of the pressure immediately behind the screw directly affects the frictional heat and thereby the melt temperature. It also appears that the normal variation of the raw material, the production capacity and the like directly changes the amount of frictional heat. The pressure behind the screw may be changed by a change of the screw rpm, the through-flow area of the screen or the discharge section with or without a change of the screw rpm, or by separate control of the plastizing section and discharge section with the possibility to change the screw rpm independent of the production capacity. A change of the pressure yields an immediate change of the amount of mechanically supplied energy to a certain amount of raw material and thereby a change of the melt temperature thereof. Accordingly a control of the plastizing or working section to a constant pressure behind the screw, at a change of the desired pressure value due to an actual temperature deviation from the desired melt temperature, will cause the desired melt temperature to be quickly obtained and main-tained independent of production and raw material variations.

When the desired melt temperature actually has been reached it has to be maintained, which may be a relatively difficult task. The metal of the adapter and tool as well as any additional equipment is a good heat conductor whereas the

melt itself is a bad heat conductor. If the metal temperature is higher than the temperature of the melt a molten layer will be formed adjacent to the metal surfaces, the molten layer being the thinner the smaller the temperature difference is. This thin molten layer reduces the friction against the metal surfaces and thereby reduces the viscosity of the melt and thereby also the flow resistance due to the reduced coefficient of friction and internal friction. If the metal temperature is lower than the melt temperature, heat energy is removed from the melt and due to the good heat conducting capacity of the metal is conducted through the metal and out into the air. Due to the good heat conducting capacity a greater specific amount of heat is removed from the melt than the amount that can be introduced therein. Hereby great temperature differences are sometimes produced between the temperature of the melt at respectively the periphery and the centre. Higher temperature of the melt results in lower viscosity which at the same pressure means higher speed of flow. This in turn means that the lowest viscosity with the highest flow velocity traces the position on the die where the flow resistance has its minimum and there produces a thickening which when the die has an annular or straight gap opening results in thickness variations in the cross direction.

If the metal temperature is controlled in such a way that it automatically traces the measured melt temperature with a desired deviation therefrom, for example so, that it exceeds the melt temperature by $+5^{\circ}$, both lower flow resistance and parallel flow are obtained whereby the risk for thickness variations in the cross direction is considerably reduced. By a temperature control as explained above it is of course even possible to adjust the metal temperature to a constant desired value. In order to obtain various optical and surface properties of the final product a certain temperature deviation from the melt temperature in the metal part of the

die gap is required, and also this may be controlled in a corresponding way.

Various modifications of the invention are obvious to the expert on the field. However, such modifications are intended to fall within the frame of the invention as defined in the attached patent claims.

CLAIMS

1. A method to control the melt temperature of plastic raw material in the manufacture of plastic products, the plastic raw material being molten in a plasticizing section from which the melt is fed to a die, characterized in that the desired melt temperature is obtained and/or maintained by a change of the amount of mechanical energy supplied to the raw material in the plasticizing section.

2. The method as claimed in claim 1, characterized in that the pressure of the melt behind the plasticizing section is used to change the amount of mechanically supplied energy.

3. The method as claimed in claim 2 characterized in that the change of the pressure of the melt behind the plasticizing section is obtained by changing the screw rpm.

4. The method as claimed in claim 2 characterized in that the change of the pressure of the melt behind the plasticizing section is obtained by changing the through-flow surface between the plasticizing section and the die alone or in combination with a change of the screw rpm.

5. The method as claimed in claim 2, characterized in that the change of the pressure of the melt behind the plasticizing portion is obtained by providing a discharge pump after the plasticizing section, said discharge pump controlling the correct amount to be discharged in combination with the change of the amount of mechanical energy supplied to the plasticizing section.

6. The method as claimed in claim 5, characterized in that the specific frictional energy in every temperature zone is maintained as constant as possible by so controlling the outside cylinder temperature so that it traces the measured

melt or raw material temperature with a desired temperature deviation therefrom.

7. The method as claimed in claim 6, characterized in that the heat energy supplied from the outside is maintained constant by adjusting the temperature of the cylinder and/or screw to a constant temperature deviation from the measured melt and/or raw material temperature.

8. The method as claimed in any of the preceding claims, characterized in that the melt temperature obtained is maintained at a constant value by controlling the metal temperature of components between the plasticizing section and the die so that it traces the melt temperature with a desired temperature deviation, preferably in the positive direction, to prevent heat from being transferred from the melt.

9. The method as claimed in any of the preceding claims, characterized in that the desired optical properties and/or surface structure are obtained by controlling the temperature of the metal in the discharge gap of the die so that it traces the melt temperature with a desired deviation therefrom.

INTERNATIONAL SEARCH REPORT

International Application No: PCT/SE88/00583

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC 4

B 29 B 7/72, 13/02; B 29 C 47/80, /92

II. FIELDS SEARCHED

Minimum Documentation Searched

Classification System	Classification Symbols
IPC 4	B 29 B; B 29 C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	DE, A, 2 054 615 (SCHENKEL GERHARD) 18 May 1972 See page 8, line 15-page 9, line 24	1-4
X	DE, A, 2 119 136 (SCHENKEL GERHARD) 16 November 1972 See whole document	1-4
X	US, A, 3 728 058 (WHEELER) 17 April 1973 See abstract, col 5, line 64-col 6, line 9, col 8, line 3-col 9, line 8 & NL, 7201911 FR, 2158183 DE, 2211916 GB, 1376638 JP, 48056752	1-3, 7, 8

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1989-01-19	1989 -01- 23
International Searching Authority	**Signature of Authorized Officer**
Swedish Patent Office	Jan Nilsson

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category*	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
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X	US, A, 4 088 430 (GILES) 9 May 1978 See col 7, line 34-col 8, line 28, col 10, ls 17-28 & US, 4168290 CA, 1079466	1-3
X	EP, A2, 0 048 819 (PAUL TROESTER MASCHINENFABRIK) 7 April 1982 See abstract, claim 1 & DE, 3036102 JP, 57087343	1-3
X	GB, A, 2 177 819 (FRIED KRUPP) 28 January 1987 See abstract & DE, 3526050 JP, 62021519 US, 4754413	1-3
X	DE, A1, 3 600 041 (REIFENHÄUSER GMBH & CO MASCHINEN-FABRIK) 9 July 1987 See col 4, line 58-col 5, line 1, claim 1	1, 4, 5
X	WO, A1, 86/06679 (FRANCIS SHAW & COMPANY) 20 November 1986 See abstract, page 4, ls 23-35 & JP, T, 62502831 EP, 0262127	1
X	DE, A1, 3 623679 (WERNER & PFLEIDERER GMBH) 28 January 1988 See col 2, ls 55-59, col 5, ls 30-60, claim 10 & FR, 2601283 JP, 63021125	1

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	Patent Abstract of Japan, Vol 9, N 51, M 361, abstract of JP 58-62755, publ 1984-10-24	1

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